

## Charged mode $Re(\epsilon'/\epsilon)$ update

Last presentation (May 13 2006): Complete 1997/1999 analysis for  $2\pi$  mode. Missing at this stage: *Ke3*  $Z$  slope and  $\pi^+\pi^-\pi^0$  attenuation measurement.

*Ke3* — analysis repeated for both years, with improved MC/selection cuts. Show consistent but somewhat larger  $Z$  slopes vs  $2\pi$  mode. Will be presented next time.

Today:  $\pi^+\pi^-\pi^0$  based attenuation measurement.

## Regenerator Transmission – intro

Uncertainties in regenerator transmission are small for  $Re(\epsilon'/\epsilon)$ ,  $Im(\epsilon'/\epsilon)$  measurements. But this is the dominant systematics for  $\Delta M$  fit.

Use  $K_L \rightarrow \pi^+ \pi^- \pi^0$ . 1999 data:

- Vacuum beam  $K_L \rightarrow \pi^+ \pi^- \pi^0$  collected with trigger 2
- Regenerator beam  $K_L \rightarrow \pi^+ \pi^- \pi^0$  collected with trigger 1

Trigger B01 = Trigger B02, but trigger B02 has neutral mode CsI readout and hardware prescale of 9.

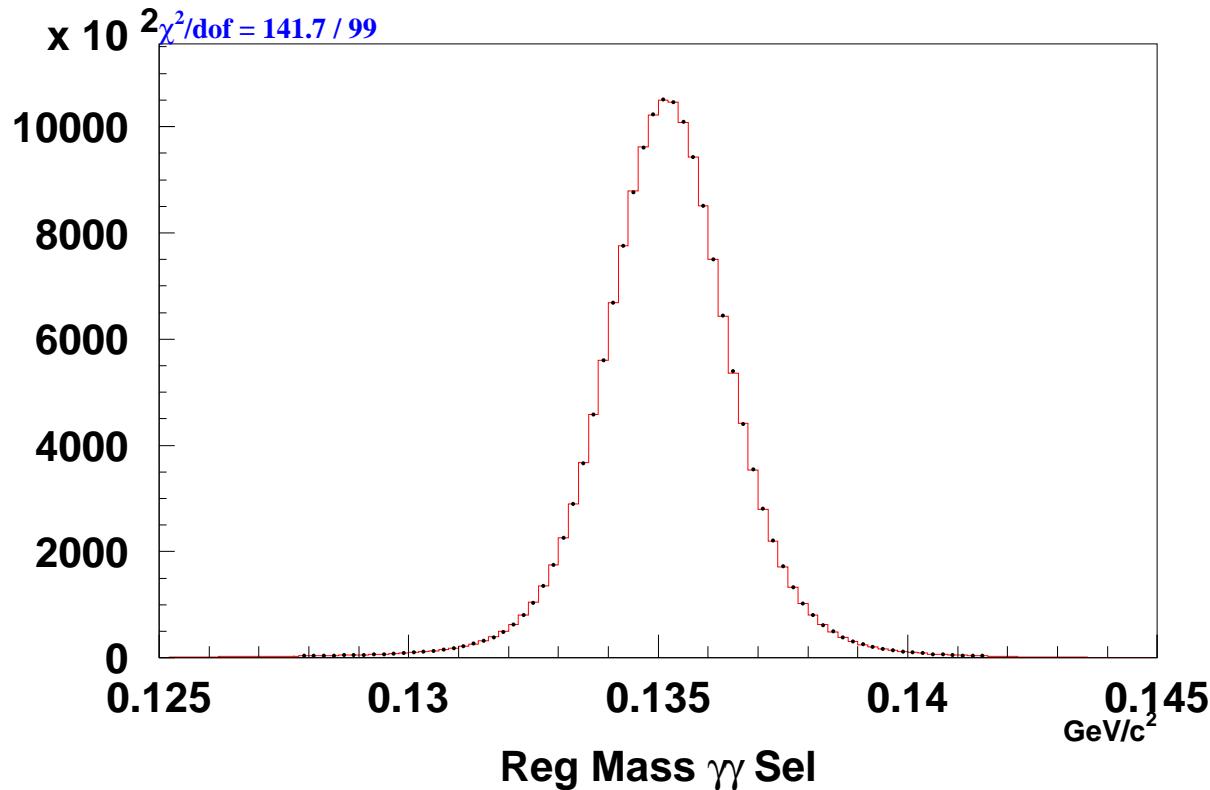
Compared to 1997 data,  $\sim 10$  fold increase in statistics in Reg. beam  $\rightarrow$  factor of  $\sim 3$  smaller stat. errors.

Total sample is **16062807** reg. beam and **1927803** vac. beam events.

## List of cuts

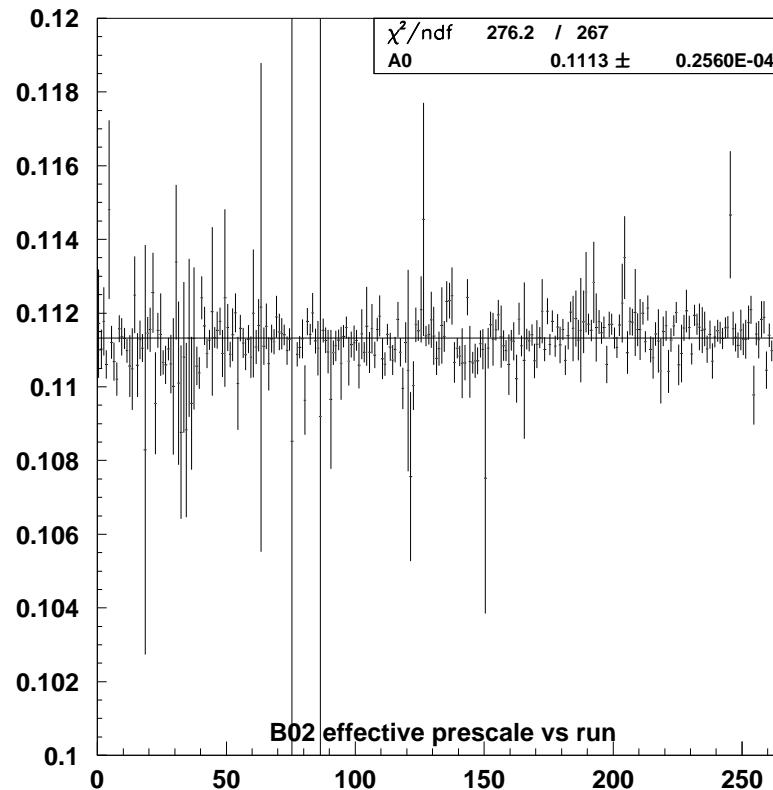
Cut	Cut condition
L3 verification	bit 3 for Vac and bit 8 for Reg beam
$P_t^2$ cut	$p_t^2 < 0.00025 \text{ GeV}^2/\text{c}^2$
Cell separation	$\text{F832CS2} >= 3$
Min. track momentum	$p > 8 \text{ GeV}/\text{c}$
Veto, fiducial cuts	Nominal charged mode cuts
Track separation at CsI	$r_{sep} > 20 \text{ cm}$
$x, y$ separation at CsI	6 and 3 cm
Track-pion separation	$R_{\gamma\pi} > 20 \text{ cm}$
Photon-photon invariant mass	$0.125 < M_{\gamma\gamma} < 0.145 \text{ GeV}/\text{c}^2$
Min. Cluster Energy	$E_g > 3 \text{ GeV}$
Vertex, Offmag $\chi^2$	$< 100, 500$
Kaon momentum	$40 < P_K < 160 \text{ GeV}/\text{c}^2$
Cluster seed cut	Remove beam/outer seed blocks
Vertex cut	$128 < Z_v < 158 \text{ m}$
Ring Cut	$R_{ring} < 110 \text{ cm}^2$

## Step 1 — equalize the beams



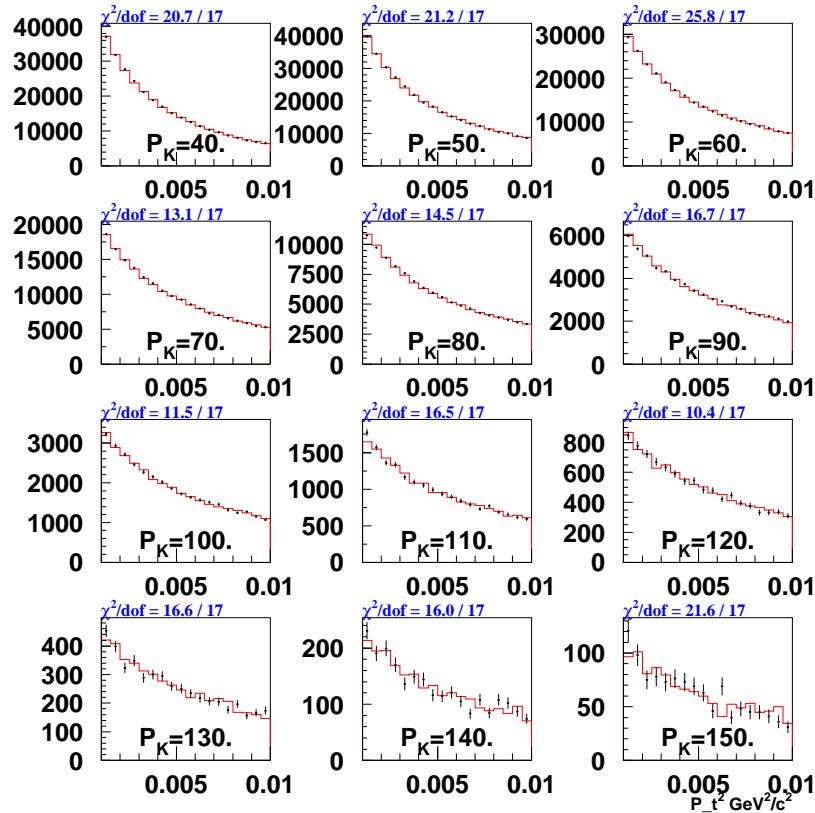
Trigger B01 and B02 have different readout thresholds. Include code from Aren Jansen to reset B02 readout to B01.

## Step 2 — check trigger prescale



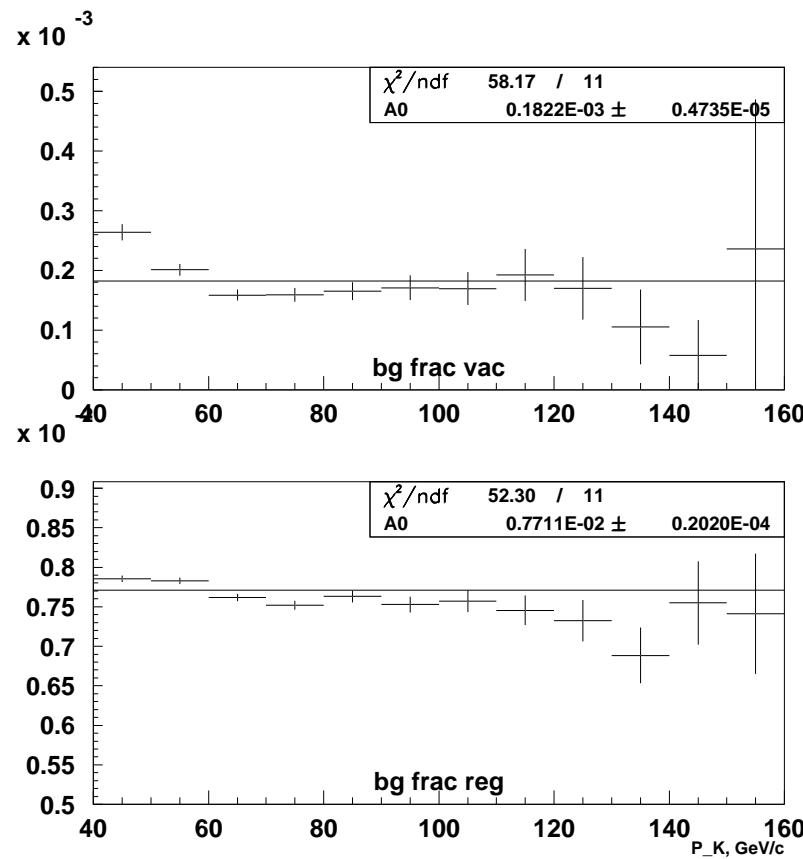
Check all  $K_L \rightarrow \pi^+ \pi^-$  taggs which are also triggered by B02.  
Measured 1/prescale  $0.111327 \pm 0.000026$  deviates from  
 $1/9 = 0.111111(1)$  Use the measured with the stat. uncertainty.

## Step 3 — subtract background



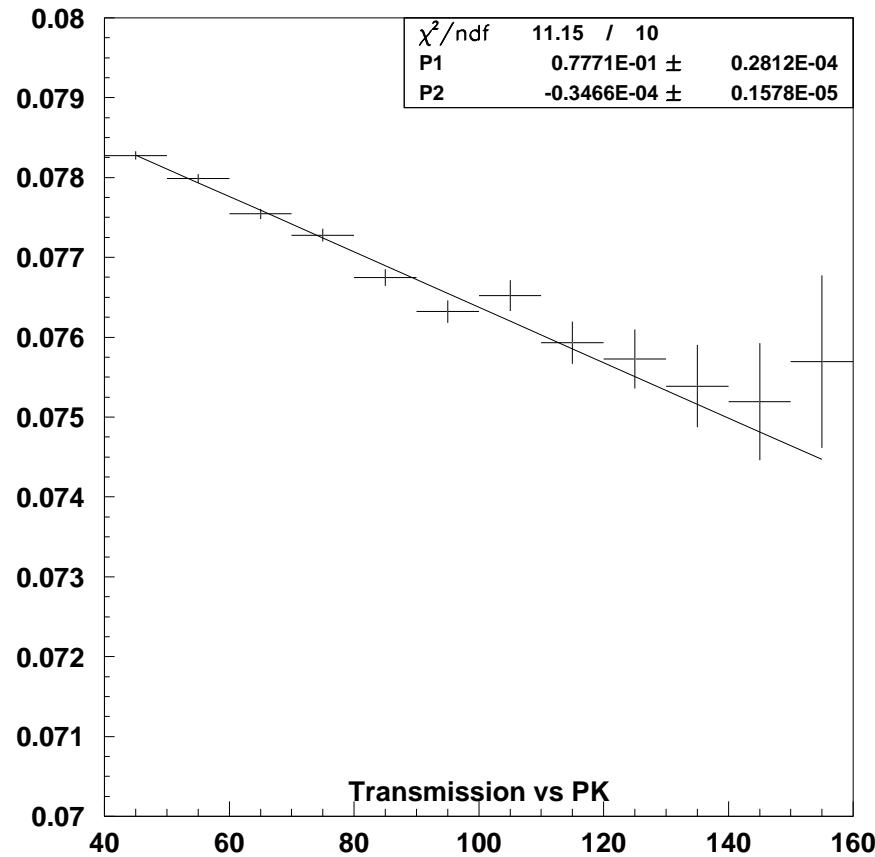
Use MC for background prediction which is tuned to 97 data.  
Sufficiently good description of  $p_t^2$  spectra.

# Background levels vs $P_K$



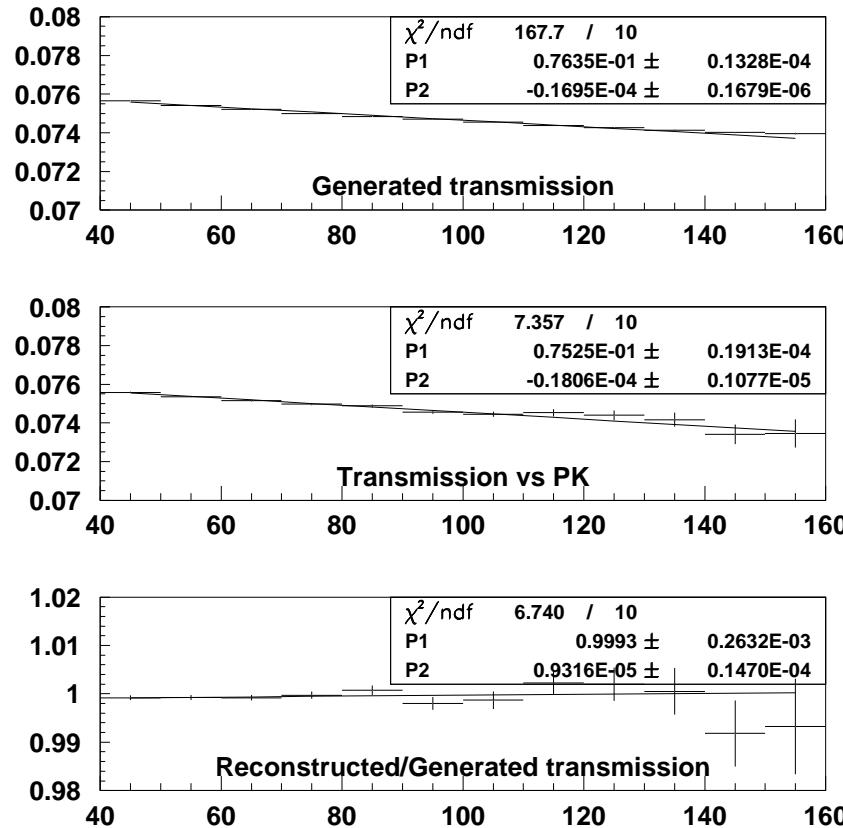
Use  $0.001 - 0.01 \text{ GeV}^2/\text{c}^2$  range in  $p_t^2$  to normalize background.  
As expected, Reg. beam background is much larger/much more important.

## Step 4 — measure raw transmission



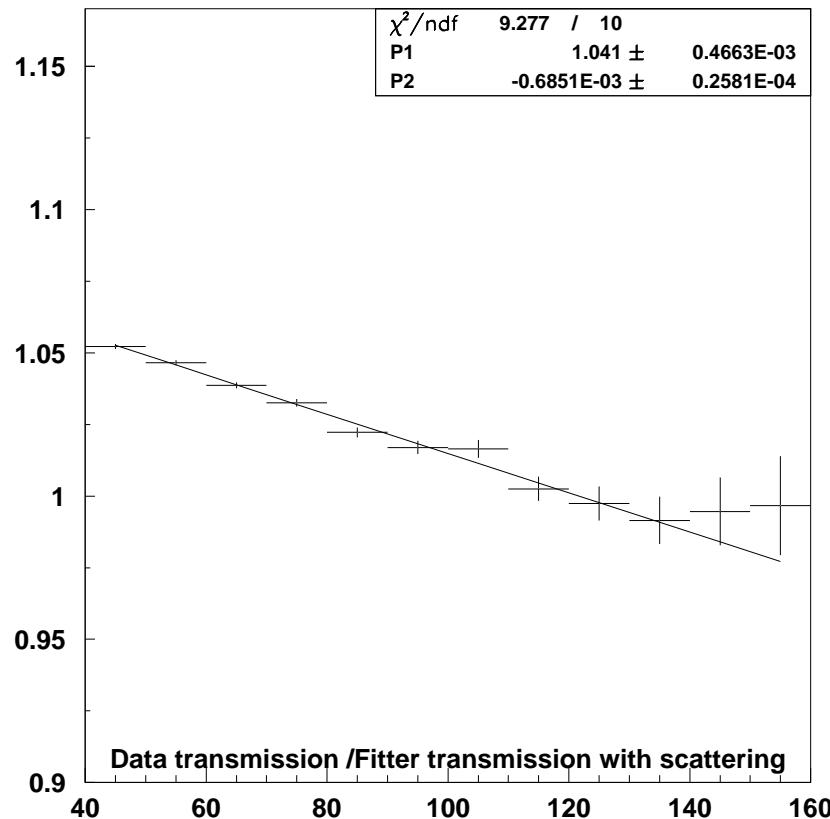
$$\frac{N_{reg}}{N_{vac}}(P_K) = N_0 + \alpha(P_K - 61.5)$$

## Step 5 — acceptance correction



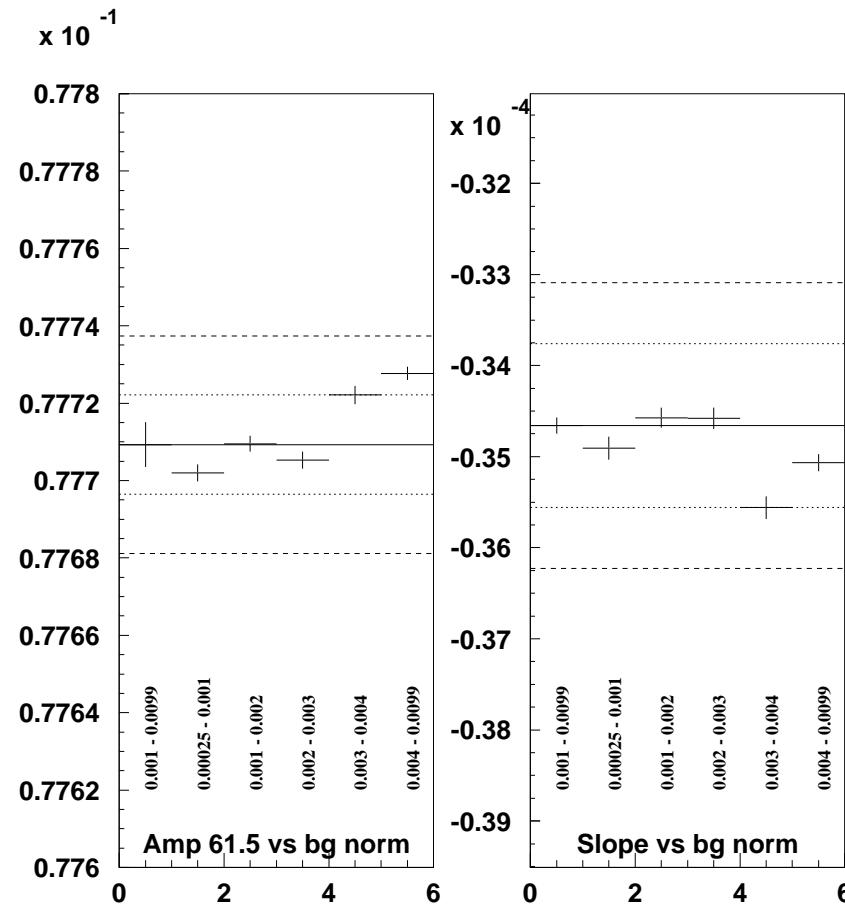
2 data sets of MC. Acceptance correction is consistent with none for the slope. Probably accidental cancellation of Ring cut/Accidental bias.

# Movable absorber scattering correction



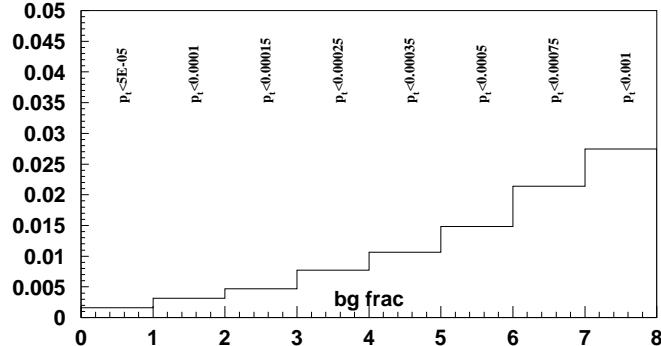
At the end we need correction to the transmission predicted in the Fitter. The Fitter has flat transmission + parameterized shadow absorber scattering correction.

# Systematic uncertainty: BG subtraction



Background fraction in Reg. beam is 0.77% — large. Estimate by varying  $p_t^2$  range used to normalize background. Uncertainty is  $\sim 2\%$  of background level.

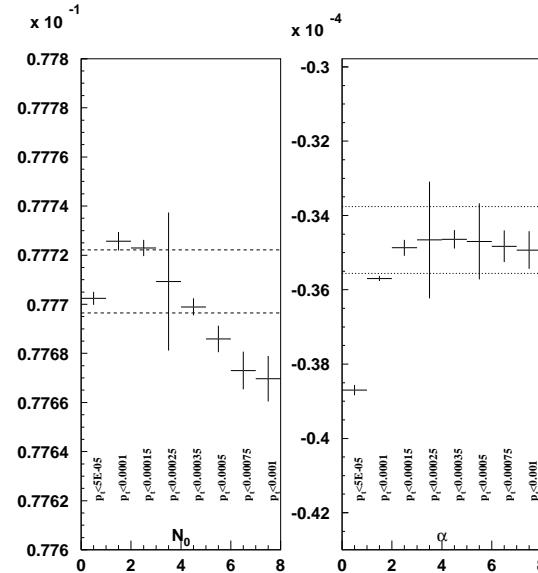
# Background systematics check



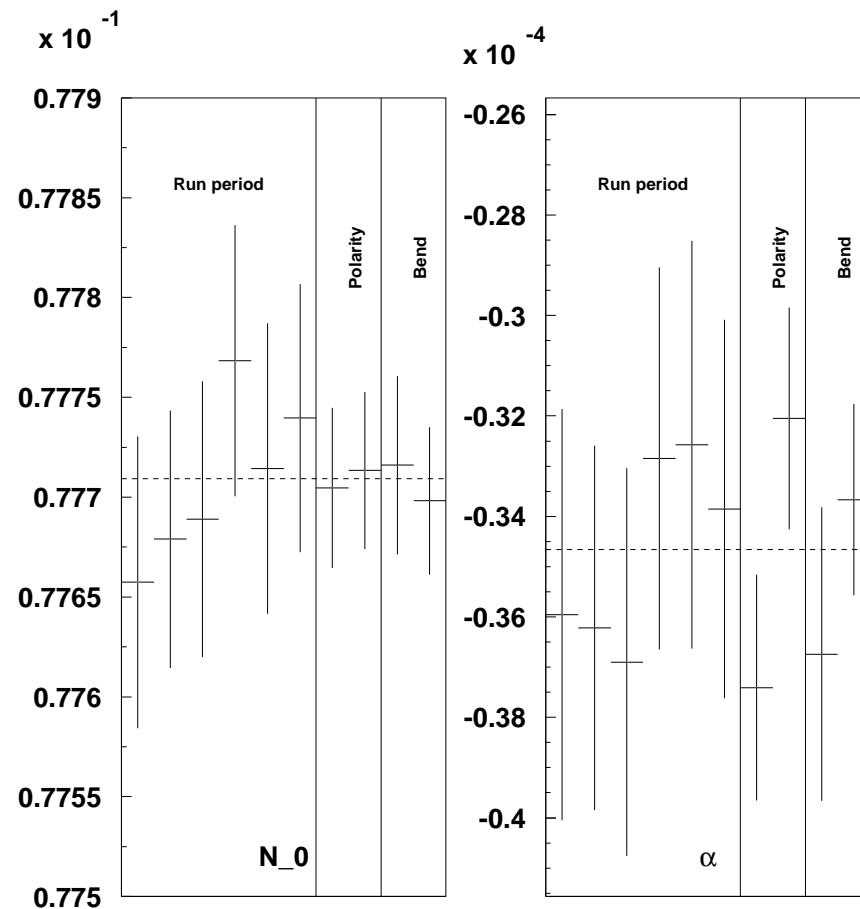
← Vary  $p_t^2$  cut from  $50 \text{ MeV}^2/\text{c}^2$  to  $1000 \text{ MeV}^2/\text{c}^2$ . Background level changes by order of magnitude.

Check stability of the attenuation measurement for this variation.

Reasonable stability within the quoted systematics.

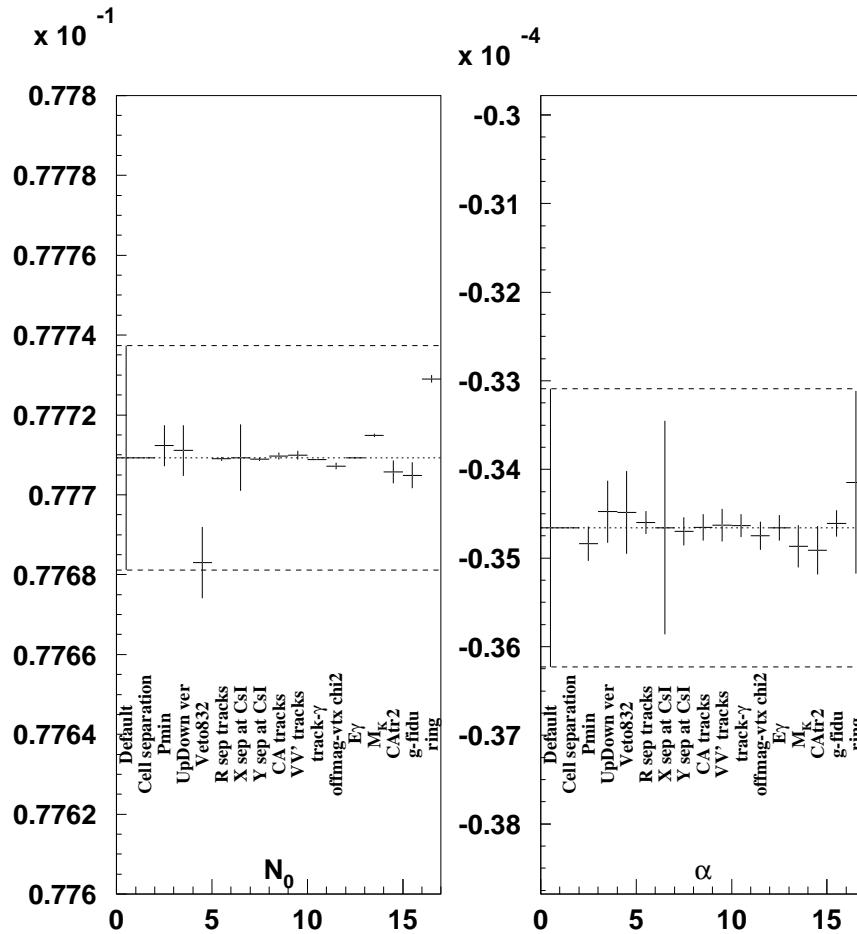


# Stability of the Raw transmission



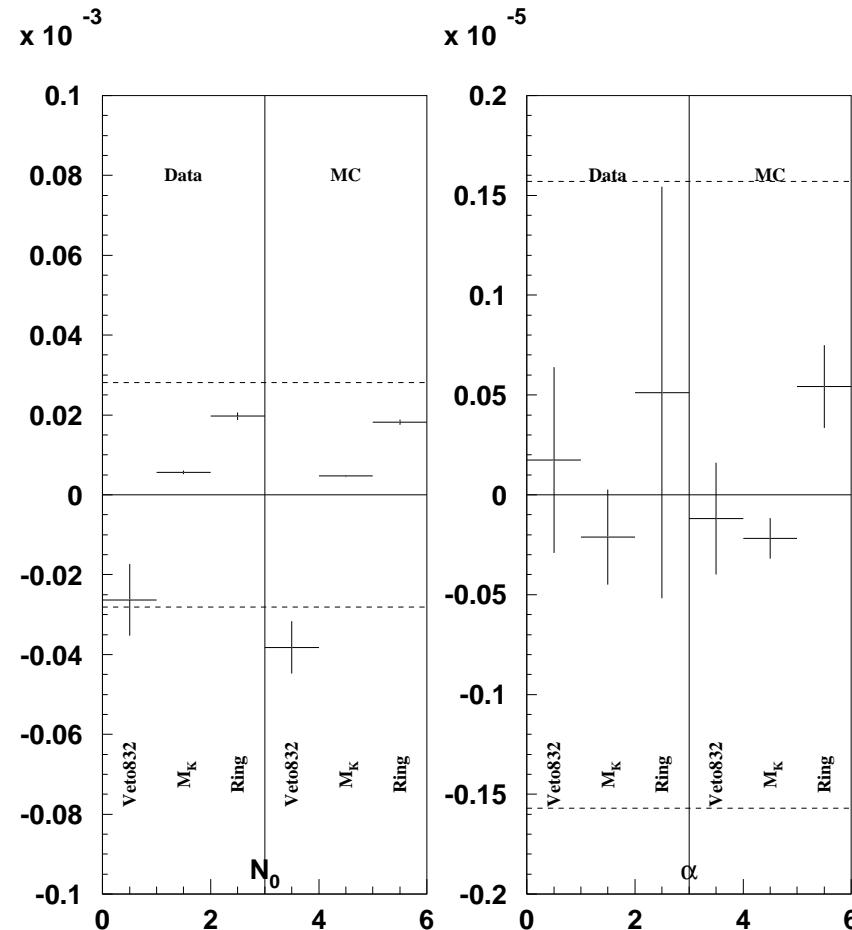
Seems to be stable.

# Cut variation for Raw transmission



There is some variation for Accidental-sensitive cuts and Ring cut ...

# Cut variation for Data and MC transmission



The bias is well predicted by MC.  $\rightarrow$  no systematic uncertainty from cut variation for the acceptance corrected attenuation.

## Summary of Systematic Uncertainties

Source	$N_0, \%$	$\alpha \times 10^{-5}$
Background Subtraction	0.0013	0.09
Trigger prescale bias	0.0018	-
Accidental bias	0.0007	0.04
Total Systematic Uncertainty	0.0023	0.10
Statistical Uncertainty	0.0028	0.16
Total Uncertainty	0.0036	0.19

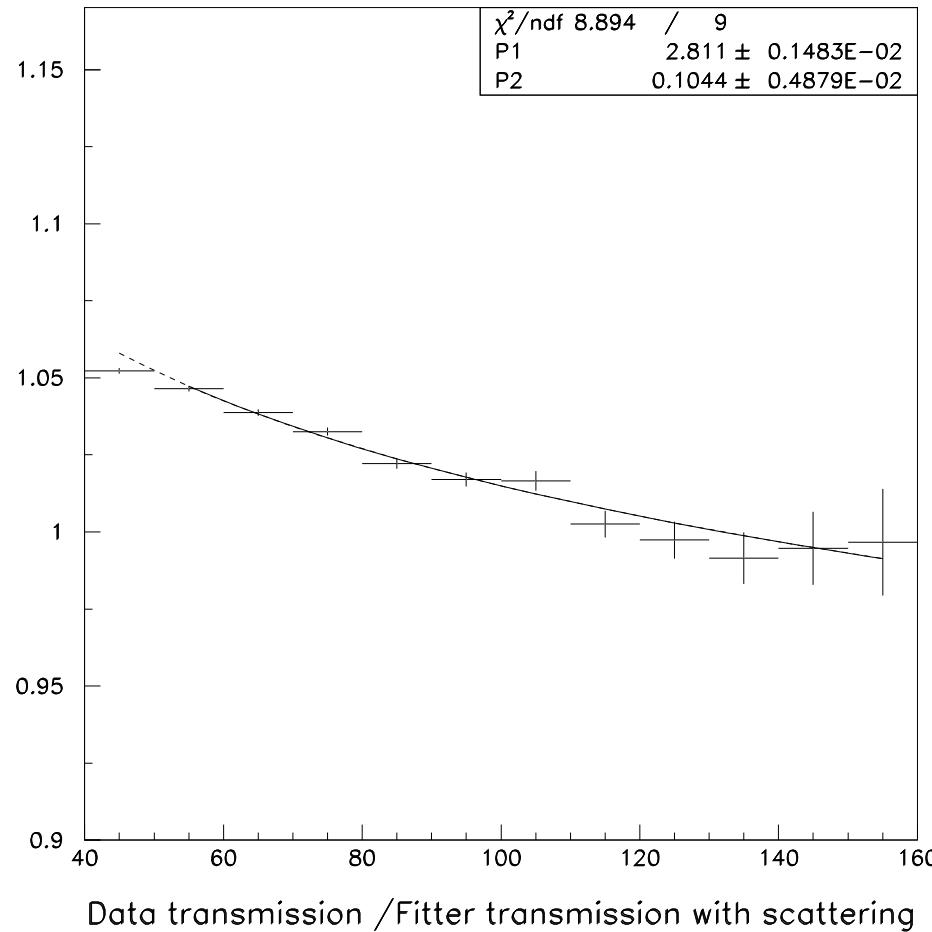
Uncertainty from the accidental bias is estimated using MC with no accidentals and taking 10% of the bias/ 68% c.l.

## Attenuation for the Fitter

Change in for	$+1\sigma$ in $N_0$	$+1\sigma$ in $\alpha$
$Re(\epsilon'/\epsilon) \times 10^{-4}$	-0.01	+0.08
$\Delta M \times 10^6 hs^{-1}$	+0.7	<b>-4.5</b>
$\tau_S \times 10^{-12} s$	-0.004	+0.011
$\Delta M \times 10^6 hs^{-1}$	+0.25	-2.4
$\tau_S \times 10^{-12} s$	-0.003	+0.004
$\phi_{+-} deg$	-0.01	+0.05
$Re(\epsilon'/\epsilon) \times 10^{-4}$	+0.00	+0.02
$Im(\epsilon'/\epsilon) \times 10^{-4}$	+0.03	+0.14

... and how uncertainties in attenuation affect the kaon system parameters. For  $\Delta M$ , uncertainty is reduced from  $10.0 \rightarrow 4.5$  units

# Attenuation and Pomeron



Fit  $\sigma \sim S^{-\alpha}$ . Get “Pomeron” slope of  $0.104 \pm 0.005$ , which seems to be a single most precise localized in  $S \sim \sqrt{P_K}$  measurement. Interpretation needs screening corrections — may help for screening systematics for other quantities.

## Conclusions

- Reg. transmission measurement is finalized.  
Impact on the kaon system parameters is estimated.
- Remaining charged mode issues are
  - Effective regenerator edge for 99 data
  - Ke3  $Z$ -slope.
  - Documentation